Bryophytes within the Vernal Pools in the Agate Desert Area of Jackson County, Oregon

Final Report

Entosthodon fascicularis (Hedw.) C. Mull. photo by Harpel

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Abstract

Bryophytes (mosses, liverworts and hornworts) play an important role in the ecosystem yet little has been done to study them in and around vernal pools. Zedler (1987) noted that an abundance of bryophytes may be found around vernal pools, mostly in moist depressions and at the upper margins of pools within and outside of the basins, but that little has been done on the ecology and taxonomy of vernal pool associated mosses. The vernal pools in southern Oregon offered an opportunity to determine which species were present and how they are distributed within the pool system. The list documents the bryophyte species associated with vernal pools in the grassland regions of the Agate Desert. A total of 42 species were found in the study areas, representing 14 families. A better understanding of the bryophyte community is essential for future planning and management of these unique vernal pool-mounded prairie ecosystems.

Introduction/Background

The Agate Desert (42° 25’ N, 122° 52’ W) falls within the middle Rogue Valley sub-region of the Klamath Mountains Ecoregion. It is a relatively flat, lowland feature located on the Rogue River Plain north of the City of Medford, Jackson County, Oregon. The landscape (~400 meters above sea level) consists of irregularly shaped soil mounds with low, often rocky areas between the mounds forming seasonal vernal pools (Elliot and Sammons 1996). The surface has been dissected by a number of shallow gullies and channels, creating small, ephemeral streams. Excluding the channels that incise into the bench, the gently inclined surface of the Agate Desert exhibits a local relief of less than one meter every 600 meters. Most of the precipitation in this Mediterranean climatic zone falls from November through March, with only 25 percent falling during the remaining seven months of the year. The average annual precipitation ranges from 460 to 760 mm. Monthly mean temperature ranges from 22.5° C in July to 3.2° C in December.

The area and distribution of the vernal pool mounded prairie grasslands has been fragmented and reduced by habitat conversion. A long history of livestock grazing, fire suppression, off-road vehicle activity, urbanization, and various hydrological alterations (e.g., road building) have contributed to the loss of native perennial plants and the establishment of many annual non-native species. The native and non-native plant species that persist fluctuate in response to the timing and duration of livestock grazing, accidental or prescribed fire, and annual climatic conditions.

Vegetation

The typical vegetation complex of the greater Agate Desert area has been characterized as a Pacific foxtail (*Alopecurus saccatus*) – popcornflower (*Plagiobothrys* spp.) association around the vernal pools (ONHP 1997). A rich diversity of vascular plants has been identified for the Agate Desert; the Nature Conservancy has documented over 300 vernal pool-mounded prairie plant species (Borgias, 2004). From this list, and other sources (USFWS 2004, 2006; ORNHIC 2005), a list of eight special status plant species, those with a life history associated with vernal pool wetland habitat, was recently compiled (ESA Associates 2006).

The natural vegetation of the Agate Desert uplands was most likely once dominated by a mixture of native perennial grasses *Pseudoroegneria spicata* (bluebunch wheatgrass), *Festuca idahoensis* (Idaho fescue), *Poa secunda* (pine bluegrass), and assorted forb species. Earlier successional species may have included *Achnatherum lemmonii* (Lemmon's needlegrass), *Elymus elymoides* (squirrel-tail), and *Bromus carinatus* (California brome).

Nonnative annual grasses *Taeniatherum caput-medusae* (Medusahead), *Bromus hordeaaceus* (soft chess), *Vulpia myuros* (rattail fescue), *Poa bulbosa* (bulbous bluegrass), and *Avena fatua* (wild oat) now dominate the upland mounds. Nonnative forbs such as *Centaurea solstitialis* (yellow starthistle), *Tragopogon pratensis* (meadow salisfy), *Verbascum blataria* (moth mullein), *Erodium cicutarium* (filaree), and *Hypericum perforatum* (Klamathweed) are also now common to observe. Native grasses are largely absent, with the exception of a few small patches. Two federally listed rare plant species endemic to southern Oregon, *Lomatium cookii* (Cook's desert parsley) and *Limnanthes floccosa* ssp. *grandiflora* (large-flowered woolly meadowfoam), as well as the listed freshwater invertebrate *Branchinecta lynchi* (vernal pool fairy shrimp), also occur in the Agate Desert.

Soils

The nearly flat surface area of the Agate Desert is characterized by a complex of two distinct soil types. This complex has been produced by the sorting of Pleistocene age alluvium, the Roxy Ann formation, into patterned ground consisting of irregular shaped soil mounds and low, rocky intermound areas. The old alluvium terraces created soil conditions that formed impermeable layers of clay that occur less than a meter below the surrounding upland mounds (Johnson 1993). Because of scale considerations soil maps lump these soils as the Agate-Winlo complex. Areas of the Winlo series soil are under the seasonally flooded pools as they are between and around areas of the Agate series soil, which form the tops of circular mounds. They are found at elevations between 335 to 560 meters (1,100 to 1,850 feet).

The intermound areas are underlain by the Winlo series. The Winlo series soil is a shallow gravelly clay loam up to 152 cm thick, with an A horizon of 0 to 10 cm. A duripan has developed in the soil and occurs at depths between 15 to 40 cm. The low intermound areas collect water in the wet season forming vernal pools. Therefore, the

Winlo soil is saturated for a least one month of the year and the surface soil is darker and slightly acidic (pH 6.2 – 6.6).

Due to the low topographic relief, the term "vernal pool swales" has been used by some researchers to describe the low areas between distinct pools where surface water will flow during intense or extended precipitation events. Once a pool has reached the full pool stage, additional water is spilled down slope into adjacent pools forming small ephemeral streams. During these wet events the surface flows may eventually collect into constructed roadside ditches or irrigation return canals where it is quickly, and unnaturally, moved away from the site (Figure 1).

This intermound area can also be classified as a "playettes" type of biological soil crust (Belnap et al. 2001). Playettes are characterized by seasonal inudations, slow evaporation of standing water and are usually covered with fine silts. Biological soil crusts are unique soil communities that are composed of mosses, liverworts, cyanobacteria, green algae, lichens, microfungi and bacteria. Although the taxa do not form a solid matt covering the ground around the vernal pools, they do help to stabilize the soil, help to retain water and provide habitat for a variety of faunal microorganisms. Also, either by direct grazing or decomposition, bryophytes are considered to be primary producers within the soil food web and nutrient cycles (Belnap 2003). The bryophyte species found in this type of soil crust have a fugitive life strategy which is characterized by an ephemeral-annual life span, high sexual reproductive effort, and an open turf growth form with spores that are usually small, very persistent and long-lived (During 1979). These characteristics allow the species to complete their entire life cycle within a very short period of time.

The mounds consist of the Agate series of well drained soils which exhibit moderately developed soil horizons and often contain gravel throughout the pedon. The soils can be about 150 cm thick. The A horizon is a dark brown loam, about 15 cm deep, with a fine granular structure. The depth to duripan is 50 to 75 cm. The chemical nature of the surface soil is slightly acidic (pH 6.2) to neutral. The effective rooting depth is 18-40 cm. It is also interesting to note that these mounds often have an abundance of rodent runs and burrows which provide suitable substratum for the bryophytes.

Methods

This survey was conducted on a gently undulating dryland landform covering a relatively small (~ 21,000 acres) area of remnant grasslands. The original extent of the grassland area is roughly equivalent to the area underlain by the Agate-Winlo soils complex (see Figure 2). The vernal pool areas were divided into three distinct zones in order to quantify the species and their distribution. These zones are: the top of the mound (the high point of the mound adjacent to the pool which remains dry during the periods that the pools are flooded); the transition zone (also called the intermound zone or swale), (the area between the open pool and the bottom slope of the mound which is seasonally inundated but does not retain standing water for a long period of time); and the pool, (the

area that may or may not be littered with cobble or rocks and retains water for the longest period of time).

For this survey the swales were identified as occurring in the intermound or transitional zone category. In addition to the three zones defined above, bryophytes were also collected at several sites established during earlier water quality studies on the Agate Desert Preserve (see Petersen 2006).

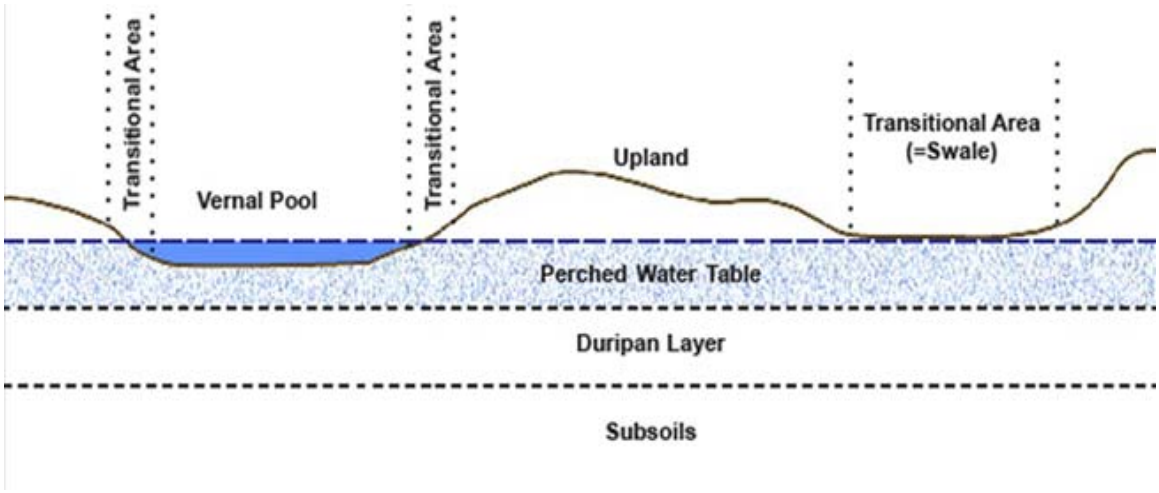

Figure 1. Simplified cross section diagram showing a perched water table above the duripan layer. The transitional area includes the wetted perimeter surrounding the pools, but may also be a low-lying swale interconnecting adjacent pools. The upland consists of Agate series soils, with Winlo series soils underlying the pools.

Study Sites

Sampling areas were originally selected based on the geographical range covered by the critical habitat units (CHU) designated for the federally listed vernal pool fairy shrimp (*Branchinecta lynchi*) in Oregon (U.S. Fish and Wildlife Service 2003). The vernal pool fairy shrimp was listed as threatened in September 1994. Within the Rogue Valley, 7,500 acres were designated as critical habitat in 2003. Critical habitat designation requires Federal agencies to evaluate the effects of any activities they fund, authorize, or carry out on listed species. While four units are recognized within the area of the Agate Desert, only the three units associated with the Agate Desert (CHUs 1-3) were sampled. Ten sampling sites were selected for bryophyte assessment within the three units. The Table Rocks Unit (CHU 4), located atop two flat-topped mesas known as Upper and Lower Table Rocks, was not sampled (see Figure 2).

- Oregon CHU 1 (Northern Agate Desert Unit). This CHU consists of eight subunits, all located north of Little Butte Creek. This unit represents the northern

limit of the fairy shrimp's habitat throughout its range and is considered significant to the species' genetic diversity.

- Oregon CHU 2 (White City East Unit). This unit consists of seven subunits, located east of U.S. 62 (Crater Lake Highway) and south and southeast of Dutton Road. The largest and easternmost of the subunits occurs just east and north of Agate Reservoir, and is the easternmost extent of the species' range in Oregon.

- Oregon CHU 3 (White City West Unit). This CHU consists of five subunits, located west of Agate Road, south of the Rogue River, and east of Bear Creek. This unit contains a good representation of the original Agate Desert mounded prairie habitat.

- Oregon CHU 4 (Table Rocks Unit). Two subunits make up the rimrock features this unit. It consists of the remnants of an ancient lava flow that filled portions of the Rogue River nearly 10 million years ago. Subsequent erosion of softer geologic layers has left these harder, andesite formations rising some 800 feet above the present Rogue Valley. Vernal pools on the Table Rocks differ from those of the Agate Desert, in that they are formed over an impervious layer of bedrock.

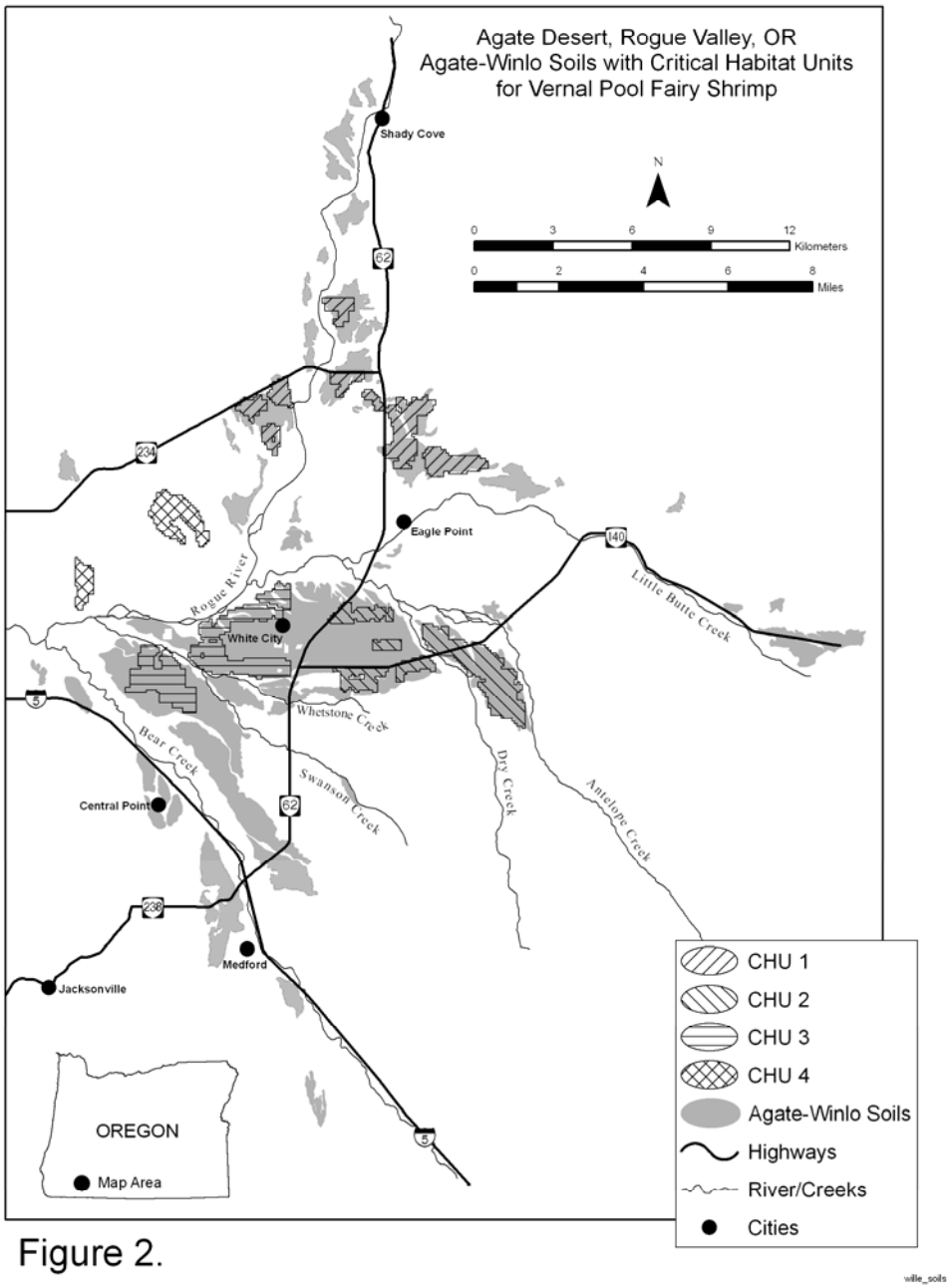

Figure 2.

A minimum of three collection locations were identified in each unit based on site accessibility, the availability of recent land management records for the site, and its assessed function and value rating from earlier studies. Earlier site surveys across the Agate Desert previously identified the most intact remaining vernal pool-mounded prairie

habitat as falling into a category described as "topographically intact with altered vegetation" (Borgias and Patterson 1999). Intuitive controlled pedestrian surveys were performed throughout the sampling units, with attention given to covering as large an areal extent of the property as possible. Data was collected from multiple vernal pool zones throughout the parcels. Samples were collected when new species were encountered. At each sample unit a complete species list was developed, noting the zone where the species occurred within the particular habitat type.

On the northern end of the valley (CHU 1) four privately owned properties, designated as sites A, B, C, and D, were sampled. In CHU 2 we sampled at one privately held land parcel and two publicly held sites where access had been previously granted to conduct surveys. In CHU 3 we accessed two privately held properties and one publically held site. With the exception of one of the northern sites (CHU 1-B) all of the collecting trips were made in the spring when the bryophytes would be mature and visible. Because bryophytes need to be identified microscopically small collections were made to identify them to the species level. These collections will be deposited in the Oregon State University Herbarium.

Sites in CHU 1

Site 1-A. This privately held property is slightly sloped towards the Rogue River to the east, although it still maintains remnants of patterned ground and is underlain with Agate-Winlo complex soils. It is currently used for leased grazing; portions of the property receive limited runoff from an adjacent road and a concentrated livestock enclosure. The surveyed area is pasture land, with some supplemental seeding with an introduced, annual sub clover cultivar (*Trifolium subterraneum*) applied to both fix nitrogen and increase the crude protein value of the pasture to livestock. Most of the area remains open grassland, with a large population of white oak encroaching from the north.

Site 1-B. This is an approximately 100 acre site held in private ownership. The owner currently leases the spring grazing rights, starting in approximately mid-March, and requires livestock to be removed by early June of each year. The entire area is covered by patterned ground; surface vegetation is a mixed complex of grasslands with large patches of buck brush and a few scattered *Quercus garryana* (Oregon white oak). Smooth cobble typifies the centers of the pools across much of the site.

Site 1-C. This approximately 157 acre site has historically been used as rangeland for cattle grazing. The site supports a high density complex of intact vernal pools and swales. The east fork of Hog Creek, an intermittent stream that has been manipulated for irrigation return-water during the summer, flows across a corner of the site. The vast majority of the site is underlain by Agate-Winlo complex soils.

Site 1-D. This site is approximately 40 acres of private land adjacent to Site C. It is bisected by a north-south running, constructed irrigation canal. A seep adjacent to the irrigation canal has created a palustrine wetland area about ½ acre in extent. The majority of the site, away from the disturbed land associated with the irrigation canal, is made up of Agate-Winlo complex soils.

Sites in CHU 2

Site 2-A. This small private land parcel of approximately 5 acres is located near the Veterans Administration Domiciliary in White City, OR. The area was once part of historic Camp White, and has not been actively managed (e.g., no grazing or other surface disturbance) since the late 1940's. An adjacent parcel was burned and tine harrowed in 2002. A portion of the property experienced an accidental fire in July 2003. One portion burned a second time the following year by an accidental fire. The site sits on Agate-Winlo complex soils and is primarily covered by grassland; a small clump of buck brush (*Ceaonothus cuneatus*) occupies an elevated mound near the center of the parcel. Bryophyte surveys on the adjacent site revealed no species present and the site was dropped from any further surveys.

Site 2-B. Approximately 2-acres of this publicly owned property contains patterned ground, and is currently occupied by the listed large-flowered meadowfoam. The larger, northern two-thirds of the property, located near Highway 62, is in the floodplain of Dutton Creek and has been excavated and expanded at stream grade to create a palustrine emergent wetland for lost function by the widening of Highway 62. Small drainageways incise into the Agate Desert landform to the south. Some past ditching to transport highway storm water runoff has likely altered the hydrology of portions of the patterned ground. The surveyed area consists of open grassland on Agate-Winlo soils.

Site 2-C. The site surveyed is known as Sub-area 1 (Reclamation 2005), and is approximately 28 acres of grassland bounded by public roads on the north and west and fence lines at the private property boundaries to the south and east. The adjacent lands are being actively grazed, but no grazing has occurred at this site for several years. An accidental grass fire burned the southern third of the site in the summer of 2006.

Sites in CHU 3

Site 3-A. The 55 acre Agate Desert Preserve was purchased by The Nature Conservancy (TNC) in 1987 as a land trust. The land was previously leased for winter and spring livestock grazing and is currently bordered by roads and an industrial complex. After the initial purchase several of the mounds were harrowed and/or dragged to "roughen them up" after re-seeding with native plant seed. The Conservancy also implemented prescribed burns in 1996, 1998, and 2002 to "reduce thatch and increase (*Lomatium cookii*) recruitment". The site is categorized as topographically intact with altered vegetation, and is located on Agate-Winlo complex soils.

Site 3-B. This 15 acre site is adjacent to the Agate Desert Preserve and was grazed using a similar management cycle up to 1987, when it was fenced off and grazing was entirely excluded. Little active management is known to have occurred since that time. A surface drainage ditch diagonally crosses the eastern quarter of the site, while the western ¾ appears relatively undisturbed.

Site 3-C. This 144 acre site was purchased by TNC in 1996 and was previously leased for livestock grazing. No grazing has been allowed since TNC purchased the land. With

Lomatium cookii seedling decline the management plan was to start mowing patches of grassland to help curtail thatch accumulation and increase seedling abundance. The southern portions of the site are dominated by White Oak and buck brush. Agate-Winlo complex soils underlay the entire site.

Results and Discussion

A total of 42 species were identified from the study area (see Table 1). Critical Habitat Unit 2 (CHU 2), although it contained the smallest total acreage of all the units surveyed, had the greatest bryophyte diversity with a total of 29 species. While this could be an artifact of a relatively longer time frame was spent surveying the four smaller sites, the higher diversity may also be attributed to less long-term disturbance at the sites which has allowed the establishment of a large number of species. Critical Habitat Unit 1 (CHU 1) was the second highest in diversity (24 species) which again may be the result of fewer disturbances at one of the sites as well as the increased number of site visits within the unit. Critical Habitat Unit 3 (CHU 3) had the fewest number of species (20) which may have resulted from the use of fire and assorted surface soil disturbance activities applied as management tools at several of the visited sites. Because bryophytes leaves are generally only one cell thick they do not respond well to a fire. Therefore, it is likely that repeated fires could prevent the bryophytes from developing a diverse flora. Frequent soil disturbance could also bury bryophyte spores too deep to germinate which could also be preventing re-colonization.

The transition zone had the greatest diversity with 86 percent of the species, followed by the pool area with 52 percent of the species. Only 26 percent of the species occurred on the mound tops. The large number of species occurring within the transition zone is most likely a result of the broad substratum diversity which ranges from the very edge of standing water to the drier margins of the mound. The periodic flooding of this area may limit competition from vascular plants during the early spring time. This moist seasonally inundated soil also provides excellent substratum for the colonization of a variety of ephemeral species such as *Entosthodon fascicularis*, *Pleuridium subulatum*, *Sphaerocarpos texanus*, and *Riccia trichocarpa*.

Although the pool area had the second highest number of species, it is important to note that most if not all of the species were found on rocks that occur within the pool. Some of these rocks are not fully submerged during periods of inundation therefore providing substratum for species that would not normally be associated with a pool environment. Two species, *Grimmia pulvinata* and *Grimmia trichophylla* were found on rocks within the pool zone and are usually above the water level when the pools are flooded. These two species tolerate hot, dry summer conditions but they can not survive long periods of being submerged in water. It is also interesting to note that none of the species collected from the pool zone are considered to be true aquatic species. Because the pools are only seasonally flooded they do not provide a suitable habitat for aquatic species. Aquatic bryophytes, although they can withstand periods of drying, usually need to be wet most of the year.

The low species diversity on the tops of the mounds was not unexpected. The dense thatch created by the various grasses and forbs makes colonization by bryophytes difficult. Two species, *Brachythecium albicans* and *Homalothecium pinnatifidum* were found on all of the mounds in the area. Both species are common and usually associated with drier disturbed sites in the Pacific Northwest. *Brachythecium albicans* often occurs in lawns while *H. pinnatifidum* occurs on soil and rocks in the lowlands. Three species, *Fissidens bryoides*, *Fissidens crispus* and *Timmiella crassinervis,* were found only in rodent runs and burrow entrances attributed to the California Meadow vole (*Microtus californicus eximius*). The vole disturbance creates open bare patches of soil that are easily colonized and provides extra nitrate loading which may be beneficial to the bryophytes. Four other small, burrowing rodents reported as abundant and native to the Agate Desert may also contribute to the distribution and diversity of the bryophyte community. Creeping vole (*Microtus oregoni*), Piñon Deermouse (*Peromyscus truei*), North American Deer Mouse, (*P. maniculatus*), and Western Harvest Mouse (*Reithrodontomys megalotis longicaudus*) have all been listed as occurring on the Agate Desert (Collins et al. 1992). See Tables 2, and 3 for a complete bryophyte species list and distribution based on location and vernal pool zone.

Five species, *Brachythecium albicans, Bryum capillare, Didymodon vinealis, Homalothecium pinnatifidum,* and *Timmiella crassinervis* were the most common mosses found in all of the sites. All of the above species have been reported from Oregon and are fairly common throughout the state. (Christy, Lyford, and Wagner 1982, Christy 1980). *Riccia* spp. was also present at all of the sites but was usually too immature to identify to the species level. It is interesting to note that *Ceratodon purpureus,* a cosmopolitan species, was not present in all of the locations. This may be a result of the thick thatch that occurs within the grasslands and the seasonal flooding of the pools.

Synopsis of the most common species:

***Brachythecium albicans* (Hedw.) Schimp. in B.S.G.**
Brachythecium albicans forms loose, whitish green mats among grasses, on outcrops slopes, and soil. It is a very common species often found growing mixed in with grass in lawns. This species was common among the grasses on top of the mounds.

***Bryum capillare* Hedw.**
Bryum capillare forms green tufts matted with reddish-brown rhizoids giving the moss a brownish cast. The leaves are twisted and contorted when dry and erect, wide spreading when moist. It occurs on moist soil, soil over rock from the lowlands to alpine areas throughout the Pacific Northwest. It occurred mostly within the transition zone, top of the mound and in a pool.

***Didymodon vinealis* (Brid.) Zand.**
Didymodon vinealis forms reddish brown to green tufts that are strongly crisped and contorted when dry. It is widespread throughout the area and occurs on soil, rock, and occasionally on trees. Within the vernal pool system *D. vinealis* occurred in the transition zone and pools.

***Homalothecium pinnatifidum* (Sull. & Lesq.) Lawt.**
Homalothecium pinnatifidum forms loose, golden green mats on sandy soil, rock or soil over rock usually on well drained slopes and on dry outcrop knobs. It is common in the lowlands of the Pacific Northwest and occurred on top of the mound, in the transition zone and once in a pool.

***Timmiella crassinervis* (Hampe) L. Koch**
Timmiella crassinervis forms dark yellowish-green, shiny tufts that are strongly crisped and contorted when dry. This species occurs on open dry patches of soil or can be scattered as clusters of individuals within a grassy area. It is common in the drier portions of the Pacific Northwest. This species occurred in all of the zones.

Conclusions

This study appears to indicate the vernal pool bryophyte flora within the Agate Desert region is diverse and well established in most of the locations. Small rodents appear to play an important role in the distribution of the bryophytes and long runs or tracks often have bare soil walls which are covered with *F. bryoides*, *F. crispus* and *T. crassinervis*, while the floors are a mixture of *B. albicans*, *H. pinnatifidum* and grasses. Older burrow entrances often have bryophyte growth on the bare soil side walls as deep as two inches and are usually bright green with new growth in the spring. This study raises several questions in regards to the role small rodents, such as the vole *M. californicus*, plays in bryophyte species composition. Do the voles transport spores; when are the runs formed and how long does it take for the bryophytes to colonize the area; does the nitrate loading help or hinder bryophyte growth?

It appears some light grazing may actually aid in the distribution of some of the more ephemeral species by providing open bare patches of soil for colonization. This was noted when several ephemeral species were found growing only within old hoof prints in one of the lightly grazed sites. Ephemeral species need open bare soil for colonization and establishment and it appears that a few hoof prints provide the right type of substratum for these species. It is important to note a spore source must be present in order to maintain populations of the more ephemeral species in the area. But again there are questions; when is the best time to allow grazing; how many animals should be allowed on site; and when should they be removed from a site? Could bryophytes be used as an indicator of “grazing health”?

What role does fire play in this ecosystem? An accidental fire on one of the sites was briefly revisited and bryophyte growth was returning in the areas that were burned, but in areas where vehicles had been driven there was little or no growth. Frequent fire may also prevent the reestablishment of the soil crust formation that is needed for both soil stability and providing a spore source for future colonization. While frequent fire may benefit the vascular plants, especially through the removal of an accumulated biomass, it appears that it prevents the establishment of a diverse bryophyte flora. The influence of a grassland fire regime - fire intensity, fire frequency, size and pattern, and seasonal timing

– must all be considered as each factor can influence which species flourish in the particular grassland.

In conclusion, this study provides a baseline species list that can be used in the future to monitor changes over time as well as raising some interesting questions about the role of bryophytes within vernal pool systems. Additional fieldwork will certainly add more species to the list and provide us with a better understanding of the species distributions, and may help to answer some of the above questions.

Acknowledgments

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Table 1. Species diversity based on location with in the vernal pool structure

Location	Top of Mound	Transition Zone	Pool
No. of Species	11	36	22
% of total species (42 total)	26%	86%	52%

Table 2. Total number of species found within the vernal pool structure per critical habitat unit.

Location	**CHU 1** (sites A,B,C,D)	**CHU 2** (sites A,B,C)	**CHU 3** (sites A,B,C)
Total number of species	**24**	**29**	**20**
% of total	57%	69%	48%
Top of mound	**4**	**9**	**6**
% of total species	9%	21%	14%
Transition zone	**15**	**27**	**15**
% of total species	36%	64%	36%
Pool	**8**	**13**	**9**
% of total species	19%	31%	21%

Table 3. Bryophyte species distribution based critical habitat unit and location within the vernal pool system

Genus & Species	M/H	CHU 1			CHU 2			CHU 3		
		top	tran	pool	top	tran	pool	top	tran	pool
Barbula spp.	M					X				
Brachythecium albicans	M	X			X	X		X		
Bryum apiculatum cf	M								X	
Bryum argenteum	M					X				
Bryum caespiticium	M		X	X		X	X			
Bryum canariense	M	X			X	X				
Bryum capillare	M		X		X	X		X	X	X
Bryum dichotomum	M		X							X
Bryum pseudotriquetrum	M		X							
Bryum spp.	M			X		X			X	
Bryum torquescens	M					X				
Cephaloziella divaricata	H					X				
Ceratodon purpureus	M	X	X						X	
Dicranoweisia cirrata	M		X				X			
Didymodon vinealis	M			X	X	X	X		X	X
Entosthodon fascicularis	M								X	
Fissidens bryoides	M					X		X	X	
Fissidens crispus	M		X		X	X	X			
Fissidens pauperculus	M		X			X				
Fossombronia longiseta	H					X	X		X	
Funaria hygrometrica	M					X			X	X
Funaria spp.	M					X				
Grimmia pulvinata	M			X		X				
Grimmia trichophylla	M			X		X	X			X
Homalothecium pinnatifidum	M	X			X	X	X	X	X	
Orthotrichum rivulare	M						X			
Philonotis capillaris	M		X			X			X	
Philonotis fontana	M		X	X						X
Pleuridium subulatum	M		X			X			X	
Pohlia cruda	M				X					
Ptychomitrium gardneri	M						X			
Racomitrium elongatum	M									X
Racomitrium heterostichum sl	M			X						
Riccia trichocarpa	H		X							X
Riccia spp.	H		X			X	X		X	X
Scleropodium touretii	M					X				
Scleropodium touretii v. *colpophyllum*	M					X				
Sphaerocarpos texanus	H		X						X	
Sphaerocarpos spp.	H					X				
Timmiella crassinervis	M		X		X	X	X	X	X	
Tortula bartramii	M						X			
Tortula ruralis	M			X	X	X	X	X		

top = top of the mound
trans = transition zone between the pool and top of the mound
pool = the shallow depression that is seasonally flooded
M = moss
H = hepatic (liverwort)

Species lists

The list includes those species observed in the study areas and does not constitute a complete survey of the vernal pool ecosystem.

Species List

Barbula spp.
Brachythecium albicans (Hedw.) B.S.G.
Bryum apiculatum Schwaegr. *cf*
Bryum argenteum Hedw.
Bryum caespiticium Hedw.
Bryum canariense Brid.
Bryum capillare Hedw.
Bryum dichotomum Dicks
Bryum pseudotriquetrum (Hedw.) Gaertn. *et al.*
Bryum spp.
Bryum torquescens Bruch
Cephaloziella divaricata (Sm.) Schiffn.
Ceratodon purpureus (Hedw.) Brid.
Dicranoweisia cirrata (Hedw.) Lindb. *ex* Milde
Didymodon vinealis (Brid.) Zand.
Entosthodon fascicularis (Hedw.) C. Mull.
Fissidens bryoides Hedw.
Fissidens crispus Montongue
Fissidens pauperculus Howe
Fossombronia longiseta Aust.
Funaria hygrometrica Hedw.
Funaria spp.
Grimmia pulvinata Sm.
Grimmia trichophylla Grev.
Homalothecium pinnatifidum (Sull. & Lesq.) Lawt.
Orthotrichum rivulare Turn.
Philonotis capillaris Lindb.
Philonotis fontana (Hedw.) Brid.
Pleuridium subulatum (Hedw.) Rabenh.
Pohlia cruda (Hedw.) Lindb.
Ptychomitrium gardneri Lesq.
Racomitrium elongatum Ehrh. *ex* Frisv.
Racomitrium heterostichum (Hedw.) Brid. *sl*
Riccia spp.
Riccia trichocarpa M.A. Howe
Scleropodium touretii (Brid.) L. Koch
Scleropodium touretii (Brid.) L. Koch var. *colpophyllum* (Sull.) Lawt.
Sphaerocarpos spp.

Sphaerocarpos texanus Aust.
Timmiella crassinervis (Hampe) L. Koch
Tortula bartramii Steere in Grout
Tortula ruralis (Hedw.) Garten. et al

Species list based on vernal pool location

Top of Mound Species
Brachythecium albicans (Hedw.) B.S.G.
Bryum canariense Brid.
Bryum capillare Hedw.
Ceratodon purpureus (Hedw.) Brid.
Didymodon vinealis (Brid.) Zand.
Fissidens bryoides Hedw.
Fissidens crispus Montongue
Homalothecium pinnatifidum (Sull. & Lesq.) Lawt.
Pohlia cruda (Hedw.) Lindb.
Timmiella crassinervis (Hampe) L. Koch
Tortula ruralis (Hedw.) Garten. et al

Transition Zone Species
Barbula spp.
Brachythecium albicans (Hedw.) B.S.G.
Bryum apiculatum Schwaegr. *cf*
Bryum argenteum Hedw.
Bryum caespiticium Hedw.
Bryum canariense Brid.
Bryum capillare Hedw.
Bryum dichotomum Dicks
Bryum pseudotriquetrum (Hedw.) Gaertn. *et al.*
Bryum torquescens Bruch
Bryum spp.
Cephaloziella divaricata (Sm.) Schiffn.
Ceratodon purpureus (Hedw.) Brid.
Dicranoweisia cirrata (Hedw.) Lindb. *ex* Milde
Didymodon vinealis (Brid.) Zand.
Entosthodon fascicularis (Hedw.) C. Mull.
Fissidens bryoides Hedw.
Fissidens crispus Montongue
Fissidens pauperculus Howe
Fossombronia longiseta Aust.
Funaria hygrometrica Hedw.
Funaria spp.
Grimmia pulvinata Sm.
Grimmia trichophylla Grev.

Homalothecium pinnatifidum (Sull. & Lesq.) Lawt.
Philonotis capillaris Lindb.
Philonotis fontana (Hedw.) Brid.
Pleuridium subulatum (Hedw.) Rabenh.
Riccia trichocarpa M.A. Howe
Riccia spp.
Scleropodium touretii (Brid.) L. Koch
Scleropodium touretii (Brid.) L. Koch var. *colpophyllum* (Sull.) Lawt.
Sphaerocarpos spp.
Sphaerocarpos texanus Aust.
Timmiella crassinervis (Hampe) L. Koch
Tortula ruralis (Hedw.) Garten. *et al*

Pool Species
Bryum caespiticium Hedw.
Bryum capillare Hedw.
Bryum dichotomum Dicks
Bryum spp.
Dicranoweisia cirrata (Hedw.) Lindb. *ex* Milde
Didymodon vinealis (Brid.) Zand.
Fissidens crispus Montagne
Fossombronia longiseta Aust.
Funaria hygrometrica Hedw.
Grimmia pulvinata Sm.
Grimmia trichophylla Grev.
Homalothecium pinnatifidum (Sull. & Lesq.) Lawt.
Orthotrichum rivulare Turn.
Philonotis fontana (Hedw.) Brid.
Ptychomitrium gardneri Lesq.
Racomitrium elongatum Ehrh. *ex* Frisv.
Racomitrium heterostichum (Hedw.) Brid. *sl*
Riccia trichocarpa M.A. Howe
Riccia spp.
Timmiella crassinervis (Hampe) L. Koch
Tortula bartramii Steere in Grout
Tortula ruralis (Hedw.) Gaertn. *et al*